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U.S. PATENT APPLICATION

FOR

IMPROVEMENTS FOR THIN-FILM TAPE HEAD PROCESSES

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Improvements for Thin-Film Tape Head Processes

Field of the Invention

The present invention relates to thin-film recording heads, and more particularly, this invention relates to improving the manufacturing process of thin-film recording heads and the structure thereof.

Background of the Invention

Conventional recording heads for linear tape drives have small transducers incorporated into a large head assembly to span the full width of the tape. For recording heads fabricated using thin-film wafer technology, this requires that the head either be fabricated individually on a wafer which is at least as wide as the recording tape and lapped individually to the proper shape, or be fabricated as a small part and assembled with larger pieces and the full assembly lapped individually to the proper shape.

Prior art FIG. **1** illustrates a wafer **100** on which a plurality of heads **102** may be manufactured. As shown, the wafer **100** includes two columns of multiple rows of heads **102**. During the fabrication of the wafer **100**, an array of heads **102** including transducers and auxiliary circuits are fabricated on a common substrate in a deposition of metallic and non-metallic layers. The auxiliary circuits are sometimes referred to as electrical lap guides (ELGs). Patterning of the array of transducers and ELGs is accomplished using photolithography in combination with etching and lift-off processes. The finished array or wafer is then optically and electrically inspected and subsequently cut into smaller arrays of heads **102**. Next, individual heads **102** are machined, at a surface **106** which will

eventually face the recording medium, to obtain a desired transducer height (sometimes referred to as the stripe height (SH) or to obtain a desired inductive transducer height sometimes referred to as the throat height (TH).

Prior art FIG. **2** illustrates a wafer **200** including a plurality of strips of closures **202** attached thereto. Such closures **202** define a plurality of slots **204** in which the aforementioned contacts **206** associated with the ELGs reside. Such closures **202** have recently become a common part of wafer processing in view of the benefits they afford in resultant heads. More information on the manufacture and use of closures **202** and the related benefits may be found with reference to US. Pat. Nos. 5,883,770 and 5,905,613 which are incorporated herein by reference in their entirety.

Prior art FIG. **3** illustrates one of the heads **300** set forth in FIG. **1** with a closure **302** attached thereto. As shown, the present head **300** is detached from a wafer. Since the head **300** is generated from a wafer structure, the head **300** is extremely thin in shape and form. In order to increase the stability of the head **300** for the suitable use thereof, the head **300** must be attached to a beam **304** of some sort formed of a rigid material. Such beams **304** are often referred to as a "U-beams." One stringent requirement in attaching the head **300** to an associated beam **304** is that the relative position of the head **300** and beam **304** be precisely aligned. Absent such alignment, the operation of the head **300** may be compromised.

There is thus a need for a method and apparatus for the precise attachment of a head **300** and a beam **304**.

Yet another problem arises when attempting to dice the heads **300** on a wafer. In the prior art, a traditional magnetic head saw blade may be used to cut the heads **300** from

the wafer. Recently, however, the use of the closures **302** such as that shown in FIG. **3** has complicated such process. In particular, the increased thickness of the material to be cut has been increased since a slight portion of the closure **302** must also be diced.

FIG. **4** illustrates a prior art saw blade **400** in the process of dicing a head **402** equipped with a closure **404**. As shown, the increased thickness of the combined head **402** and closure **404** cause the blade to slightly bend due to the cutting forces resulting from cutting the additional material. This bending, in turn, results in non-planarity in the operating surface **406** of the head **402**.

There is thus a need for a method and apparatus capable of dicing a head equipped with a closure while maintaining the planarity of the head operating surface.

FIG. **5** is an end view illustration of one particular type of bidirectional tape head. As shown, a head **560** is provided with a flat transducing surface **561** and a row of transducers on the surface of gap **562**. An electrical connection cable **563** connects the transducers to the read/write channel of the associated tape drive. Alumina overcoat **564** protects the transducers and forms a slope discontinuity edge with respect to the flat transducing surface **561**. A slope discontinuity edge **565** is formed parallel to the gap **562** at the side of the flat transducing surface **561** opposite the gap surface.

To control the overwrap angle of the tape **566** at edge **565**, an outrigger **567** is provided. The outrigger **567** may be formed by cutting a groove **568** in the head **560**. A taper **569** may be lapped on the outrigger **567**, preferably at an angle about midway between the expected wrap angles the head will be presented with for various cartridges. The depth of the taper **569** is controlled so that the line from edge **565** to edge **570** is at the desired overwrap angle with respect to the flat transducing surface **561**.

The head penetration into the tape **566** of a cartridge is controlled so that at the minimum wrap angle **571**, the tape just touches the edge **570**. Thus, for various cartridges, the tape wrap can move between the positions indicated by **571** and **572**, while the outrigger **567** maintains a constant wrap angle onto the flat transducing surface **561**. More information on the head design shown in FIG. **5** may be found with reference to U.S. Patent No.: 5,905,613, which is incorporated herein by reference in its entirety.

Unfortunately, the above design requires two actions to afford the accompanying benefits, namely the cutting of the groove **568** and the lapping of the taper **569**. As is well known, each action that is required during the process of thin-film magnetic head manufacture creates much expense.

There is thus a need for a technique of affording the benefits of the groove **568** and taper **569** of FIG. 5, with less of a manufacturing expense.

DISCLOSURE OF THE INVENTION

A plurality of apparatuses and methods are provided for improving the manufacture and operational characteristics of thin magnetic film heads. First provided is an apparatus and method for bonding a beam and a magnetic head with optimal precision. Also included is a saw apparatus capable of dicing magnetic heads on an associated wafer in a manner that affords a planar operating surface on the magnetic head. Still yet, a specific head structure is provided which has single a groove that affords all of the benefits of the prior art head structures, but with only one action required during the thin-film head manufacturing process.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and advantages of the present invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings.

Prior art FIG. **1** illustrates a wafer on which a plurality of heads may be manufactured.

Prior art FIG. **2** illustrates a wafer including a plurality of strips of closures attached thereto.

Prior art FIG. **3** illustrates one of the heads set forth in FIG. **1** with a closure attached thereto.

Prior art FIG. **4** illustrates a prior art saw blade in the process of dicing a head equipped with a closure.

Prior art FIG. **5** is an end view illustration of a particular type of prior art bidirectional tape head.

FIG. **6** is a perspective view of an apparatus for precisely attaching a thin-film head to a beam.

FIG. **6A** illustrates an exploded view showing the various components of the apparatus of FIG. **6**.

FIG. **6B** illustrates a method for precisely attaching a thin-film head to a beam.

FIG. **7** illustrates a side view of a strengthened saw blade capable of affording heads with a planar operating surface, in accordance with one embodiment.

FIG. **8** is a side view of the saw blade taken along line 8-8 of FIG. **7**.

FIG. **9** shows the saw blade of FIGs. **7** and **8** while dicing heads on an accompanying wafer.

FIG. **10** is a perspective view of a magnetic head equipped with a single groove, in accordance with one embodiment.

FIG. **11** is a cross-sectional view of the groove taken along line 11-11 shown in FIG. **10**.

FIG. **12** illustrates the head of FIGs. **10** and **11** in use, in accordance with one embodiment.

BEST MODE FOR CARRYING OUT THE INVENTION

The following description is the best embodiment presently contemplated for carrying out the present invention. This description is made for the purpose of illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein.

Beam and Magnetic Head Bonding Apparatus

FIG. **6** is a perspective view of an apparatus **600** for precisely attaching a thin-film head to a beam. As will soon become apparent, this is accomplished by allowing relative alignment of the head and the beam in six directions **601**. Such directions **601** are shown in the lower right-hand corner of FIG. **6**. For further detail regarding the components of the present apparatus **600** of FIG. **6,** FIG. **6A** illustrates an exploded view showing the various components along with the associated fasteners, couplings, etc. of the apparatus **600**.

In the context of the present embodiment, a head may refer to any magnetic head capable of operating (i.e. reading, writing, etc.) in conjunction with a tape. Further, the beam may refer to any rigid support that may be attached to the head for support purposes. In one embodiment, the beam may take the form of a "U-beam."

A base **602** is provided including a head mounting assembly **604** positioned thereon. The head mounting assembly **604** includes a pair of stanchions **606** fixedly mounted on a first side of the base **602**. A pivot arm **608** is provided having a first end pivotally coupled to the stanchions **606** about an axis parallel with an x-axis. See

directions **601**. The pivot arm **608** further has a second end with a handle **610** and a head holder **612** coupled thereto for securely and precisely receiving a head thereon.

As shown in FIG. **6**, the head holder **612** is attached to a plate **618** which is in turn screwably coupled to the second end of the pivot arm **608** for allowing the placement of a shim **620** between the plate **618** and the second end of the pivot arm **608**. The use of the shim **620** in this manner allows the adjustment of the head in a θz direction. See directions **601**.

The head mounting assembly **604** further includes a vacuum assembly **614** coupled to the head holder **612** via a hose **616**. Optionally, the vacuum assembly **614** includes gauges and a control switch for controlling purposes. In use, the vacuum assembly **614** serves for securing a head thereto utilizing a vacuum, in a manner that will soon become apparent.

As an option, a lever (not shown) may be provided for facilitating the extraction of the head from the head holder **612**. In use, the lever may be used to eject the head against the force of the vacuum. As yet another option, the pivot arm **608** may be biased against one of the stanchions **606** in order to abate any "play" in the pivoting of the pivot arm **608**. This is done to ensure no movement in any direction other than the pivoting action about an axis parallel to the x-axis.

Also provided is a beam mounting assembly **622** including a support member **624** having a first portion **626** with a rectangular configuration having a first height. The support member **624** of the beam mounting assembly **622** is fixedly mounted on a second side of the base **602**. The support member **624** is positioned along an axis parallel with the x-axis. The support member **624** further includes a second portion **628** with a

rectangular configuration having a second height greater than the first height. The second portion **628** of the support member **624** is fixedly mounted to the base **602** adjacent to the first portion **626** of the support member **624**.

The beam mounting assembly **622** further includes a beam holder **630** positioned on a top surface of the second portion **628** of the support member **624**. The beam holder **630** includes a pair of short end edges and a pair of long side edges. The beam holder **630** is adapted for receiving a beam **632** thereon.

The beam holder **630** includes an x-axis stopper **634** positioned at a first one of the short end edges of the beam holder **630** for abutting the beam **632** when positioned on the beam holder **630**. It should be noted that the beam holder **630** is slidably coupled to the top surface of the second portion **628** of the support member **624** in a direction parallel to the x-axis. By this structure, adjustment of the beam **632** is permitted along the x-axis. As an option, such sliding may be controlled by use of a screw **636** that is rotatably coupled to the support member **624** and screwably coupled to the beam holder **630**.

An intermediate member **638** of the beam mounting assembly **622** is equipped with a size and shape substantially similar to the first portion **626** of the support member **624**. In use, the intermediate member **638** is adapted for being positioned on top of the first portion **626** of the support member **624** and further along a side of the second portion **628** of the support member **624**.

The intermediate member **638** includes a pair of smooth holes formed at ends thereof in parallel with a y-axis. See FIG. **6A**. Such smooth holes are sized for loosely receiving a pair of screws **640** which are in turn screwably coupled to a side of the second

portion **628** with at least one shim **642** therebetween. The augmented size of the holes is adapted for allowing adjustment of the beam **632** along the y-axis and in a θx direction by way of the shim **642**. See directions **601**.

The intermediate member **638** further includes a pair of threaded holes (see FIG. **6A**) formed completely therethrough at ends thereof, each along an axis parallel with a z-axis for screwably receiving a pair of screws **644**. Such screws abut a top of the first portion **626** of the support member **624** for allowing adjustment of the beam **632** along the y-axis and in a θy direction.

Still yet, the beam mounting assembly **622** includes an upper member **646** having a lower slider segment **648** with a rectangular configuration. The lower slider segment **648** of the upper member **646** of the beam mounting assembly **622** is slidably coupled to a top of the intermediate member **638** along an axis parallel with the y-axis. Such slidable coupling is preferably controlled by way of a screw **649**.

This may be accomplished by positioning the lower slider segment **648** in a track formed in the intermediate member **638.** Further, a rotatable coupling may be provided between the screw **649** and any fixed portion of the base **602** or support member **624.** Moreover, a screwable coupling may be provided between the screw **649** and the lower slider segment **648**. Of course, any other means of accomplishing the same may be employed.

An upper pivoting segment **650** of the upper member **646** is pivotally coupled at a first side **652** thereof to the lower slider segment **648**. Such coupling is performed formed about an axis parallel with the z-axis. The upper pivoting segment **650** further has a second side **654** defining a y-axis stopper for abutting the beam **632** along a first

one of the long side edges of the beam holder **630**. By this design, macro adjustment of the beam **632** is afforded along the y-axis.

As an option, a spring **655**(see FIG. **6A**) may be coupled between the upper pivoting segment **650** and the lower slider segment **648**. Such spring serves for biasing the second side of the upper pivoting segment **650** away from the beam **632**. Associated therewith is a screw **656** screwably coupled to an arm extending from the lower slider segment **648**. In use, the screw **656** may be used for abutting the upper pivoting segment **650** to selectively determine an extent to which the upper pivoting segment **650** pivots toward the beam **632**. This in turn allows micro adjustment of the beam **632** along the y-axis.

Yet another component of the present embodiment is a pair of stabilizers **660** each with a first end **661** having a spring-biased pin **662** mounted therein and an intermediate portion **663** pivotally coupled to the base **602** along an axis parallel with the z-axis. A second end **664** of each of the stabilizers **660** is slidably situated on a top surface of the base **602**. Such second end is adapted for being fixed with respect to the base **602** via a clamp **667**.

The stabilizers **660** includes a first stabilizer **668** with the pin **662** thereof adapted for abutting the beam **632** along a second one of the long side edges of the beam holder **630**. A second stabilizer **670** is provided with the pin **662** thereof adapted for abutting the beam **632** along a second one of the short end edges of the beam holder **630**.

In use, the head mounting assembly **604** is adapted for attaching the head secured in the head holder **612** with the beam **632** secured in the beam holder **630** upon the pivoting of the head mounting assembly **604**. Prior to pivoting, the beam **632** and head

may be precisely aligned along six (6) degrees of freedom, namely along an x-axis, y-axis, z-axis, θx direction, θy direction, and θz direction.

FIG. **6B** illustrates a method **6000** for precisely attaching a thin-film head to a beam. In one embodiment, the present method **6000** may be carried out in the context of the forgoing apparatus **600**. Of course, however, the present method **6000** may also be implemented in the context of any desired machine.

Initially, in operation **6002**, the relative position of a head holder and beam holder is adjusted along an x-axis, y-axis, and z-axis and further in a θx direction, θy direction, and θz direction. As mentioned earlier, such adjustment is carried out so that the head is precisely attached to the beam. Next, in operation **6004**, a head is attached to the head holder of the head holder mounting assembly. This may be accomplished utilizing a vacuum assembly, or any other desired mechanism.

Next, a beam is attached to the beam holder of the beam mounting assembly. Note operation **6006**. The head holder is then pivoted relative to the beam holder for attaching the head to the beam. See operation **6008**. It should be noted that the vacuum assembly may be disengaged at this point.

<u>Improved Saw Blade Apparatus</u>

FIGs. **7** through **8** illustrate a rigid saw blade **700** for dicing a thin-film head from a wafer in a manner that prevents non-planarity in a surface on which the tranducers of the head operate on an associated tape. As mentioned earlier during reference to prior art FIG. **4**, conventional saw blades are subject to bending due to the increased thickness of the wafer resulting from the use of closures. This bending of the saw blade, in turn,

results in non-planar head surfaces which affords less than optimal operational characteristics.

FIG. **7** illustrates a side view of a saw blade **700**, in accordance with one embodiment. As shown, the saw blade **700** is equipped with a substantially thin circular configuration. The saw blade **700** further has a serrated periphery **702** for cutting heads from an accompanying wafer. As will soon become apparent, the saw blade **700** includes an outer portion **704** and a thickened inner portion **706** each with a disk-shaped configuration. As shown in FIG. **7**, the thickened inner portion **706** has a diameter less than ½ the diameter of the outer portion **704**.

FIG. **8** is a side view of the saw blade **700** taken along line 8-8 of FIG. **7**. As shown, the saw blade **700** has a planar first face **710** and a second face **712**. The planar first face **710** has the thickened inner portion **706** of the saw blade **700** integrally attached thereto. Further, the outer portion **704** has a first thickness while the thickened inner portion **706** has a second thickness greater than the first thickness. In one embodiment, the first thickness is at least twice the second thickness.

FIG. **9** shows the saw blade **700** of FIGs. **7** and **8** while dicing heads **900** on an accompanying wafer **902**. As shown, such heads **900** are equipped with closures **904**. In the context of the present description, a closure **904** may include any member integrally, adhesively or otherwise attached to a head **900** for enlarging an operating surface thereof. In operation, the saw blade **700** is adapted for cutting the wafer **902** along one of the closures **904** such that a surface of one of the heads **900** is exposed in coplanar relationship with a surface of the closure **904** attached thereto.

As shown in FIG. **9**, the diameter of the thickened inner portion **706** is such that the thickened inner portion **706** resides on a side of the saw blade **700** opposite the closure **904** when cutting the wafer **902**. This results in the thickened inner portion **706** extending within a gap defined by the closures **904**.

By this design, the saw blade **700** is supported by the thickened inner portion **706** and resists any forces that would cause the saw blade **700** to bend. To this end, the surfaces of the resulting heads **900** are substantially planar, and thus exhibit improved operational characteristics.

<u>Single Groove Magnetic Head</u>

FIGs. **10** and **11** illustrate a magnetic head with a single groove formed therein for accomplishing the benefits of prior art magnetic head devices. As mentioned earlier, prior art magnetic head devices include an intermediate groove to afford a discontinuity edge adjacent the operating surface of the head. Moreover, a lapped surface is provided in order to provide control over the overwrap angle of the tape. See prior art FIG. **5**.

FIG. **10** is a perspective view of a magnetic head **1000** equipped with a single groove **1002**, in accordance with one embodiment. As shown, the magnetic head **1000** is provided with a head body **1004** having a substantially rectangular configuration. The head body **1004** includes a top face **1006**, a bottom face **1008**, a pair of elongated side faces **1010**, and a pair of short end faces **1012**. At least one transducer **1016** is formed in communication with the top face **1006** of the head body **1004**.

Also provided is a closure **1018** with a substantially rectangular configuration. The closure **1018** has a length substantially equal to the head body **1004**. Further, the closure **1018** is coupled to a first one of the side faces **1010** of the head body **1004**

coincident with the top face **1006** thereof. The single groove **1002** is formed in the top face **1006** of the head body **1004**, and extends between the transducers **1016** and a second one of the side faces **1010**.

FIG. **11** is a cross-sectional view of the groove **1002** taken along line 11-11 shown in FIG. **10**. As shown, the groove **1002** is defined by a first surface **1020** positioned in a plane substantially parallel with the side faces **1010**. Such first surface **1020** is defined by edges coincident with the top face **1006** and the end faces **1012**. Note FIG. **10**.

The groove **1002** is further defined by a second surface **1022** positioned in a plane substantially parallel with the top and bottom faces (**1006** and **1008**). The second surface **1022** is defined by edges coincident with the first surface **1020**, the end faces **1012** and the second one of the side faces **1010**.

In use, the groove **1002** serves for providing a discontinuity edge **1100**. Moreover, the groove **1002** controls an overwrap angle of a tape sliding along the at least one transducer **1016**. This is accomplished by setting a depth of the groove **1002** which in turn selectively positions an outrigger edge **1102**. Both the discontinuity edge **1100** and the overwrap angle control are thus afforded with a single cut during the manufacturing process, thus reducing an overall cost in producing the head.

FIG. **12** illustrates the head of FIGs. **10** and **11** in use, in accordance with one embodiment. As shown, FIG. **12** illustrates the head of FIGs. **10** and **11** for a read-while-write bidirectional linear tape drive. "Read-while-write" means that the read transducer follows behind the write transducer. This arrangement allows the data just written by the

write transducer to be immediately checked for accuracy and true recording by the following read transducer.

Specifically, in FIG. **12**, two heads **1275** and **1276** as illustrated in FIG. **10** and **11** are mounted on U-beams **1277** which are, in turn, adhesively coupled. The wrap angle onto the flat transducing surfaces **1278** and **1279** of the tape **1280** is created by the U-beams **1277**.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.